XIV.—*Notes on the Freshwater Infusoria of the Island of Bombay.* No. 1. *Organization.* By H. J. Carter, Esq., Assistant Surgeon H.C.S., Bombay.

[With three Plates.]

For some time past, when circumstances would permit, I have paid considerable attention to the Infusoria and Freshwater Algæ of the Island of Bombay, which being the same, generally, as those of Europe, have not occupied me much in specific description, while they have left me comparatively uninterrupted in their structural and physiological observation. How much has been gained by the latter the following summary of my "Notes" will show.

I shall commence with the freshwater Rhizopoda, the *Astasiæ* and *Euglenæ*; but before proceeding to remark on them separately, I would premise some observations on the general organization of Infusoria, and these will be arranged under the following heads:—

Pellicula, or skin.
Diaphane, or transparent moving matter.
Sarcode, or abdominal mucus.
Moleculæ, or minute grains.
Granules, or large grains.
Digestive Globules, or spherical spaces which enclose the food.
Spherical Cells, or biliary organisms. (?)
Vesicula, or "contracting vesicle."
Nucleus.
Ovules, or embryonic cells.
Spermatozoids. (?)
Impregnation.
Development of Ovule.

Pellicula.—This term has been proposed by Mohl for the consolidated surface of material which has no distinct enclosing membrane*. Dujardin, in allusion to the tegumentary covering of *Amœba,* &c., likens it to the film which occurs over "flour-paste or glue allowed to cool in the air†;" and the same view of it will be taken here. It is at first inseparable and undistinguishable from the tissue which lies beneath it, yielding in every way to the form which the latter assumes. As, however, *Amœba* progresses in development, and its activity begins to diminish, the pellicula appears to thicken and harden, al-

* Mohl on the Structure of Chlorophyll. Ann. & Mag. Nat. Hist. vol. xv. p. 325, foot-note. May 1855.
† Hist. Nat. des Zoophytes Infusoires, p. 29 *et seq.*

though it still retains great tenacity; and thus the expansions of the subjacent tissue are seen to burst through it in much the same manner that the end of a stream of lead bursts through its pellicle. Finally, when all activity ceases, and the *Amœba* becomes stationary (by fixing itself to some neighbouring object through a pedicular prolongation of the pellicula), a new layer of the latter is formed below the old one, and thus the capsule is formed, and the pellicula replaced on the body of the *Amœba*, until the latter becomes firmly encysted (Pl. V. figs. 6, 8)*. To what part of the body of the *Amœba* the pedicular process corresponds, I am ignorant; but it is interesting to see that in *Euglena*, where a similar process takes place, it is the anterior extremity which is next the pedicle (fig. 9). Many freshwater Rhizopoda secrete a testaceous covering, which increases in size with the animal; but the fleshy part of the body being for the most part free, is of course still covered with pellicula. The pellicula forms the surface-covering of *Astasia* and *Euglena* †, as well as that of all the *holo-*, *poly-*, *diplo-* and *mono*-ciliated flexible animalcules and zoospores. Here too, probably, the cilia themselves are also covered with it, though secreted by subjacent organs, analogous perhaps to those which secrete the hairs on the bodies of higher animals,—a supposition that would appear ridiculous did we not find such a correspondence between the vital processes of the highest and lowest developments as to induce us to think the latter are but a repetition of the others on a smaller scale; that is to say, effected by similar agents, of corresponding minuteness, conducted on the same principle. Taking the above view of the pellicula, we must regard it as a structureless product, which hardens after secretion. May we not infer that there is a layer below, specially organized for its formation?

Diaphane.—By this name I would designate the moving substance on which the pellicula rests (figs. 1–3). *Amœba*, whose primary figure is spherical, has the power of changing this into an almost unlimited number of secondary forms, most of which, being attended with root-shaped prolongations, this Infusorium is justly entitled to a place among the Rhizopoda.

* After this the numbers alone of the figures will be inserted, as they are continuous throughout the three plates.

† Although *Astasia* and *Euglena* are here mentioned together, it seems that, in classification, one should be on the animal, and the other on the vegetable side of *Amœba*; for *Astasia* possesses a mouth and complicated buccal apparatus for biting off and taking in food, while *Euglena* appears to have no mouth, and to be nourished by endosmosis. The half-developed cilium, too, in *Euglena*, compared with the strong prehensile organ which occurs in *Astasia*, with many other points which will be mentioned hereafter, allies the former as much more to the zoospore or gonidium of the Algæ, as the reverse does the latter to the higher Infusoria.

That the diaphane is structureless and transparent, so far as our microscopic powers extend, may be seen by the travelling of some kinds of *Amœba* across the field of the microscope, in which the coating of the diaphane, though broader all round than the diameter of the turbid mass of contents in the centre, only now and then, when the light is favourable, comes into view. The radii in *Actinophrys* are wholly devoid of turbid material, except towards the base; and the advancing border of the *Amœbæ* generally is always transparent (figs. 2 *a*, 3 *a*). But whether granules are mixed with it or not, the diaphane by itself, that is the contracting material, in the present state of our microscopic powers, must be characterized by transparency and motion, without apparent structure. It has the same appearance and polymorphic power in *Difflugia*, *Euglypha*, and *Arcella*, as in *Amœba*; but in *Astasia* and *Euglena*, though still possessing great latitude in this respect, it can put forth no prolongations, and, consequently, the primary forms of these families are never entirely lost. This latitude is still more limited in *Oxytricha*, *Plœsconia*, *Paramecium*, &c., though in many Infusoria of this class it has still the power of temporarily producing considerable alteration in shape. It might be stated that the diaphane cannot be demonstrated in these animalcules; but the great power of motion of their tegumentary covering, combined with transparency, warrants the use of the term here just as much as in Rhizopoda, where it is only more striking, because, for want of cilia, the animalcule is compelled to put it forth in delicate expansions and prolongations, in progression, and for the capture of its food;—indeed, these are the two great modes in which all its vital movements are effected.

Some might think, from what has been stated, that there is no difference originally between the pellicula and diaphane, and that the latter passes into the former when the animalcule becomes encysted. But neither appears to be the case; for if we watch *Amœba* or *Euglena* undergoing this process, the activity and accompanying polymorphism of the diaphane are diminished only by the thickening and consolidation of the cyst, until the latter is fully formed, when they cease altogether. Subsequently, however, in *Euglena*, when this animalcule becomes temporarily encysted, the diaphane separates itself from the last layer of pellicula which completes the cyst, and thus the *Euglena* becomes free within it; after which it will force off the constricted peduncle of attachment from the object to which the cyst may have been fixed, and, projecting its cilium through the broken part, swim about for some time, until (perhaps by increase of size) the cyst is altogether burst, and its liberation restored (fig. 9). Yet it might still be observed, that this is no proof of the cyst and diaphane having been originally distinct structures, —the diaphane may have been re-formed; in which case I can only refer to what I have suggested respecting the origin of the pellicula, and add that what takes place generally in the higher organisms appears to me to be applicable to the lower ones. Certainly we do not find one structure erected by the organism of another in the former, but the production of each structure dependent on the presence of its proper organism *ab initio*; that is, that the structure does not appear before it is accompanied by the fully developed form of the cell or organism which produces it. I do not question that, under the laws of vitality, one organism may occasionally take on the excretory or secreting functions of another, nor that, from a common stock, all organisms, in obedience to the same laws, may be adapted to that which is particularly required of them; but I think that when once a being is fully developed, each organ of which it may be composed has its peculiar organism, and that organism its peculiar duties, which, except in unusual instances, are the only ones that it is capable of performing. That the diaphane, therefore, should pass into the pellicula, or the pellicula be secreted by the diaphane, seems untenable.

Related to the diaphane is the transparent intercellular substance of *Spongilla*, which has a polymorphism equally great with the fully developed cells. This, however, can only be satisfactorily seen when the new sponge is growing out from the seed-like body, at which time it spreads itself over the glass in a transparent film, charged with contracting vesicles of different sizes, and in various degrees of dilatation and contraction. How this substance is produced so early it is difficult to conceive, since it seems to come into existence independently of the development of the sponge-ovules, which are seen imbedded in it, and there undergoing their transformation into sponge-cells. The spicula too are developed synchronously with the advancing transparent border, from little glairy globules about the size of the largest ovules, which send out a linear process on each side, and thus gradually grow into their ultimate forms. Perhaps the only way of accounting for the early appearance of this intercellular substance is to consider that it is a development from some remnants of the original protoplasm, and then that it has the power of secreting a general pellicula, while at the same time it is in part the general diaphane; and perhaps possesses also the power of producing new sponge-cells, as we see the protoplasm in *Vorticella* and the roots of *Chara* producing new buds, viz. independently of the cell-nucleus.

Sarcode.—This name was proposed by Dujardin for the "glutinous substance of the interior" of Infusoria*; and we shall here understand it as applicable solely to what, in other words, might be termed the "abdominal mucus" (figs. 1 *b*, 2 *b*, 3 *b*). The sarcode occupies the centre, while the diaphane and pellicula form the circumferential layers of Infusoria; besides this, it is the seat of the "granules" and other organs of the interior, and appears to receive the food directly into its substance. From the greater latitude of the particles which are situated towards the centre, that portion may be inferred to be of less density than the rest; and sometimes, when the animalcule is rendered spherical by aqueous distension, there appears to be an actual cavity here (fig. 2 *d*); but as I am not certain about the real situation of the water under these circumstances, I shall return to this point again by-and-by. In the Rhizopoda generally, the sarcode appears to have no external communication, and hence the food must pass into it directly through the diaphane; but in most of the other Infusoria it communicates with the surrounding medium by one orifice at least. The same kind of substance occupies a good portion, if not the whole, of the internal or abdominal cavity of *Astasia* and *Euglena*, *Vorticella*, *Paramecium*, and the Infusoria of this class. When death is about to take place, it comes forth from *Vorticella*, *Paramecium*, &c. in round, transparent, structureless expansions; and even during life in *Stentor* a portion may be made, by pressure, to issue through a rupture of the pellicula without any apparent injury to the animalcule†. *Otostoma*‡, also, when under pressure, throws off portions of its sarcode through the anal orifice, containing a number of the "spherical cells," to be mentioned hereafter, with which it is charged in this kind of infusorium. As we shall presently find that the portions of food which are received into the midst of the sarcode are circulated round the abdominal cavity, it seems necessary to admit, also, that the sarcode is endowed with a power of motion, in which we cannot help seeing an analogy to that motion which exists in the alimentary canal of higher animals.

In *Euglena* the sarcode is separated from the diaphane by a layer of pointed, sigmoid fibres, arranged parallel to each other, so as to form in *Crumenula texta*, Duj., a conical cell, which, as soon as the ovules have become developed, and the diaphane and other contents of the sarcode have died off, becomes transparent, but still retains its conical form until the resiliency of the fibres,

* *Op. cit.* p. 35.

† Ehrenberg, *ap.* Dujard. *op. cit.* p. 34, foot-note. It is the same with *Nassula*.

‡ Ann. & Mag. Nat. Hist. vol. xvii. pl. ix. figs. 6–8, 1856.

now unrestrained by the diaphane and other soft parts, cause dehiscence, and the ovules are set at liberty (Pl. VI. fig. 60). May we not infer that the siliceous frustule of *Navicula* is similarly situated to this fibrous layer, and that it also derives its power of motion from an external coating of diaphane? That there is a gelatinous layer external to the frustule probably in all *Diatomeæ*, may frequently be seen, although it may not be always endowed with mobility. In a species of *Palmellea* too, like *Glœocapsa granosa*, Kg.*, which I have had under observation, the transparent external covering ("envelope-cell" of Cohn) not only at one period presents an actinophorous form, but also moves about under this condition, bearing the green elliptical cell within (singly, or divided into two or four, &c. as the case may be), whose form depends upon the presence of a more or less firm (skeleton) coat, that corresponds in position and office to the spiral coat in *Euglena* and the siliceous frustule in *Navicula*, viz. in supporting the contents of the sarcode and chlorophyll-bearing protoplasm, and in sustaining their form in all these organisms respectively (fig. 19). In *Oscillatoria* (*princeps*, Kg., mihi) again, although, like *Navicula*, the presence of a layer of substance endowed with motion round the cells cannot be seen, yet, when we observe the whole chain of a fragment moving slowly backwards and forwards within its sheath, and even extending beyond it, so as to force out the loosened cells at either end (probably for the formation of new filaments), we can come to no other conclusion, that I see, than that each cell, which corresponds in office to the frustule in *Navicula*, &c., is surrounded by a transparent, gelatinous substance, endowed with motion, and that, *en masse*, they perform this act: although this substance cannot be seen when the cells are undergoing simple elongation or filamentous development, yet it becomes evident enough when they are undergoing crucial division without the sheath for the multiplication of filaments. In none of these instances does this envelope, if existing in *Navicula*, as well as the rest, present any change on the addition of iodine but a yellow tinge, even when assisted by sulphuric acid; and it therefore appears to be entitled just as much to the term of diaphane in *Navicula* (if present), *Glœocapsa granosa* (?), and *Oscillatoria*, as in the Infusoria. In *Closterium* there are no signs of an organ of this kind externally, except at the extremities, where it may be an extruded part of the ciliated protoplasm within; for *C. lunula*, as Morren has stated, can fix itself by one end, and partially rotate upon that end; while in *Spirogyra* this much extrusion of the protoplasm

* *Hæmatococcus granosus*, Hassall, pl. 81, fig. 6, British Freshwater Algæ;—but with cells scattered, not continuous.

is not permitted, and the cell is here closed after the manner of vegetable cells generally. What further strengthens the view that there is in some Diatomeæ (*e. g. Navicula* and *Nitzschia*) a layer corresponding to diaphane on the surface, is, that there is some prehensile and transporting organ here, which undoubtedly has the power of seizing particles that come in contact with it, and of conveying them partially or wholly backwards and forwards from one extremity of the frustule to the other, or of retaining them on any part of it stationarily.

Moleculæ.—We will apply this term to the minute, colourless granules with which the sarcode is charged (fig. 3 *b*). They differ in size, and are the first bodies that appear in it; but whether they be of different kinds, have any particular office, or undergo any further development, I am at present ignorant. *Amœba*, *Astasia* (fig. 45), and *Euglena* (fig. 46), in the earlier part of their existence, respectively seem to contain nothing else but this molecular sarcode, the nucleus, and contracting vesicle; afterwards the "granules" appear, and last of all the ovules, both of which are developed in the sarcode amongst the moleculæ. By the time the ovules have become fully formed, the sarcode and its moleculæ have died off, or disappeared (figs. 26, 46, 56).

Granules.—This name is intended for certain large granules, which make their appearance among the moleculæ, and are circulated round the abdominal cavity in the manner of the digestive globules and particles of food (figs. 4 *a*, 5 *c*, 65 *a*). They are of different sizes, but chiefly characterized by being much larger than the moleculæ, few in number, of a circular, elliptical, elongated, sub-round, or irregular shape, with thick dark edges, apparently produced by obstruction to the passage of light,—colourless, or of a yellowish-green tint. When large, and with no other granular matters present but the moleculæ, they form a striking feature in the interior of *Amœba, Vorticella, Oxytricha, Paramecium aurelia*, &c.; but at times they are so insignificant in size as to be undistinguishable from the moleculæ, even if present at all. That they are not ovules may be satisfactorily seen when both are together; the dark, thick, and frequently irregular edges and colourless state of the former contrasting strongly with the thin, circular margin and faint yellow tint of the latter (fig. 5 *c*). They appear to increase in size and number with the age of the infusorium, and, when fully developed, to remain unaltered in size, though apparently somewhat shrivelled in form, until their dissolution. On one occasion, while watching the metamorphosis of an *Oxytricha* (similar to, but not the same as that described by M. Jules Haime*, and of which I

* Ann. des Sci. Nat. t. xix. p. 109, Zool. 1853.

hope to give a detailed account hereafter), these granules, during the formation of the globular cell within the body, which enclosed the materials from which the *Plæsconia* was ultimately developed, became congregated together at the posterior extremity of the *Oxytricha*, and remained there in a roundish mass, shut out from the cell, until the latter burst for the liberation of the *Plæsconia*, when, with the deciduous coverings, they passed into dissolution. Of the nature of their office I am ignorant, but they are sufficiently remarkable and constant to demand particular notice.

In the development of the sponge-cell, a similar set of large granules makes its appearance at a very early period, and increase in number and size until they form as remarkable a feature as those above noticed. At this time they are about $\frac{1}{10000}$ of an inch in diameter, of an elliptical shape, and of a light amber colour by transmitted light; they are the colour-bearing granules or cells of *Spongilla*, and give the colour of chlorophyll to this organism when it becomes green.

Such granules would appear to be present also in the earliest forms of *Amœba*, since they may be seen in *mono-* and *diplo-*ciliated monads, which, on losing these appendages, become polymorphic, and assume all the characters of *Amœba*. Here they not only resemble the granules of the sponge-cell, but at the same time appear to be of the same kind as those above described. Neither is it uncommon to see polymorphic cells, precisely like *Amœba*, bearing granules coloured like those of the sponge-cell; but the resemblance between the two organisms is so great, when the latter is free, that it is impossible to say which is which: however, they are greenish-yellow and elliptical-elongate in the foot of *Difflugia proteiformis*, Ehr., which cannot be confounded with the cell of *Spongilla*. That these granules are not ovules in the sponge-cell, any more than in the Infusoria, their colour alone is sufficient to determine.

Digestive Globules.—We shall use this term for spherical spaces of the sarcode, which are filled with water, and generally contain more or less food (figs. 3 *e*, 65 *b*, 74 *d*). They are formed in *Vorticella* and *Paramecium* in the following way, viz. as the particles of nutritive matter are drawn into the vortex of the buccal cavity, by the cilia which are disposed around its orifice for this purpose, they are forced down, with a certain amount of water, into the sarcode at the end of it, where they at first form a pouch-like dilatation, which sooner or later becomes constricted close to the buccal cavity, and, having been thus separated from it, passes off in a spherical form into the midst of the sarcode (figs. 65 *c*, 74 *c c*). The formation of one globule is soon followed by that of another; and so on successively the food, with a large quantity of water, is taken into the abdomen; sometimes the globule appears to contain nothing but water. When in the sarcode, it is continually undergoing circulation round the abdominal cavity, until the whole of its contents are digested, and resolved into a fluid, or until their nutrient parts are abstracted; the remainder then, still in a globular form, if there be sufficient water left to sustain this, is cast off through the anal orifice, as it arrives opposite this point during rotation (fig. 68 *b*). Frequently, however, nothing but the crude ingesta remain; for as soon as the globule begins to be circulated, the watery contents begin to be absorbed,—hence some particles of food are almost always present, without any globule round them (fig. 5 *d*); added to which, in many instances bodies pass directly into the sarcode without any globule at all (fig. 74 *e*). I cannot, with some others, think, that there is any intestinal canal in the abdominal cavity, because the digestive globules and other particles of food are constantly undergoing circulation round the *whole* of its interior. In *Vorticella*, particles of food may occasionally be seen to circulate throughout, and accumulate, in every corner of its interior, particularly those which do not happen to be enclosed in globules (fig. 74 *e e*). Moreover, the intimate resemblance which exists between the alimentary organs of higher Infusoria, viz. *Nassula*, *Otostoma*, &c., and those of the binocular and so-called blind *Planariæ*,—in the distance of the mouth from the anterior extremity, the presence of a buccal apparatus, and a simple sac-like stomach in the latter, lined with a layer of mucous substance (sarcode?), charged with the "spherical cells" about to be described, is so great, that with such a simple gastric organ in an animal so closely allied to these Infusoria as *Planaria*, I do not see what reason we have, in descending the scale, to expect a more complicated digestive apparatus; but, on the contrary, one still more simple, in which there would be no stomach at all;—a condition which appears to me to be common to all the Infusoria that have come under my notice.

In the *Amœba*, for want, apparently, of a channel of communication with the exterior, the introduction of food seems to take place directly through the diaphane; and it is only now and then that the process by which the digestive globule is formed can be distinctly seen. Thus, on one occasion, where the particle about to be enclosed was a small *Amœba*, the latter, after struggling for some time, got under the former, when the large *Amœba* raised its diaphane in a dome-shaped cavity over the small one, and then, closing in below, after the manner of a sphincter, shut in the small *Amœba*, which, with a portion of water, immediately passed into the sarcode, under the form of a spherical digestive globule*. That the food is broken down by a digestive process in this way may be seen in the *Amœba*, where it frequently appears in all degrees of solution in the same individual; viz. from an opake, crude mass, to a blue or brownish fluid, according to the colour which the material may assume under its altered condition. In *Astasia* digestive globules also appear; but here the food is taken in through a distinct mouth, while in *Euglena* the absence of such vesicles would appear to indicate that its support is of a different kind, if not introduced in a different way.

Spherical Cells.—These cells, to which I have just alluded, abound in the sarcode of *Otostoma*†, and apparently in many of Ehrenberg's Allotreta (fig. 92). In *Otostoma* they are of different sizes, because they are in all stages of development; and, to keep up their numbers, without distending the animalcule, they must be continually undergoing rapid decay, as well as reproduction. The most remarkable feature in them is, that the largest, besides other granular bodies, contain several small cells, filled with a brownish-yellow fluid, and these cells are also found free among the general group; but what their ultimate destination is, as they do not appear to grow larger, or to become reproductive, I am ignorant. In the *Planariæ* to which I have alluded, as well as in Rotifera, such cells nearly fill the stomach, and the large ones being more or less grouped together in the former, at the same time that they chiefly contain the yellow cells, the whole acquires a sub-acinous or glandular appearance, very like the hepatic element surrounding the alimentary canal of some of the lower worms. It is also interesting to find here that each possesses a lash of cilia (about 50) projecting from one part of the cell, which, for some time after they are forced into the water through the oral orifice, or a rupture of the body, act by their whipping movements as imperfect locomotive organs, while, when these cells are fixed *in situ*, the same whipping movement must keep up a continued agitation of the gastric contents, which, if not conducted in a similar way in the Infusoria, has its analogue there in the circulation of the digestive globules, and granular matters of the sarcode (fig. 92 *a*, *g*). Although ovules may occasionally issue together with these cells from *Otostoma*, &c. as well as from the *Planariæ*, yet the two can hardly be confounded; as in the *Planariæ* the peculiar character of the ovule not only distinguishes it, but by careful manipulation the whole generative apparatus may be exposed outside the stomach.

* Ann. & Mag. Nat. Hist. vol. iv. p. 93, 1849.
† *Idem*, vol. xvii. pl. ix. fig. 6 *b b*.

That these cells in *Planaria* and *Otostoma* are homologous organs can hardly be doubted, both from their general characters and their correspondence in position; but what their office may be is at present unknown. Occurring, however, as they do, in the stomach of *Planaria* and Rotifera, where there is no other analogue of the so-called biliary follicles of the lower worms*, and being almost identical in *Otostoma* and *Planaria*, they not only ally these two organisms, but, at the same time, appear to be the homologue of the biliary follicles in each.

I have never seen any cells of this kind in *Amœba*, unless the "granules" already described be their analogues. It appears evident that these are the same both in *Amœba* and the sponge-cell, and that they are the seat of the green colour in the latter. Are the green granules of the sponge-cell analogous to the parts or cells respectively which hold the colouring matter or endochrome in the *Diatomeæ*, *Closterium*, *Spirogyra*, *Cladophora*, &c., and (through the latter) to the "green disks" or peripheral layer of chlorophyll-bearing cellules in the internode of *Nitella*, and those which, scattered irregularly through its moving protoplasm, are circulated round the cell of *Serpicula verticillata* (figs. 63 *a*, 64 *a*)? If so, the chlorophyll-bearing parts of the protoplasm in vegetables may be the analogue of the liver in animals. In some Rotifera the spherical cells appear to bear bile as green as grass or chlorophyll†, while in others it is yellow. The same diversity of colour occasionally manifests itself in the *Diatomeæ*; while in *Spirogyra* especially, the oil-globules and amylaceous deposits, which abound in abortive conjugation, are entirely confined to the green spiral-bands, thus corresponding, in one identically, and in the other transitionally, with the fat and sugar which are formed in the liver of man; the colouring matter in all of course being, when present, a mere indication *cæt. par.* of the nature of the organ. How the colour-bearing cellulæ of the spherical cells are produced in *Otostoma*

* By this I do not mean to class the Planarians with the Worms. Mr. C. Girard, who has followed out the "Embryonic Development of *Planocera elliptica*," would ally them to the Gasteropoda,—'Researches upon Nemerteans and Planarians,' 4to, Philadelphia, 1854.

† Since writing this, I have seen *Diglena catellina*, Ehr., discharge the green matter from its alimentary canal, and retain nothing but the ordinarily coloured biliary cells; also *D. caudata* to have the whole of the soft tissues of its body coloured in this way, unless there be diverticulations of the stomach to this extent; so that I now begin to think this colour, which at first appeared persistent, to be adventitious, and gained from the *Euglenæ*, and, perhaps, chlorophyll-bearing protoplasm on which these species chiefly feed. Accidentally, perhaps, the bile may become green in any species of Rotifera, as in animals generally; and this appears to be the case with the endochrome of *Diatomeæ*.

and *Planaria,* I am ignorant; but in some Rotifera (*e. g. Brachionus Pala,* Ehr.) they present themselves at an early period in a circular or discoid group, attached to the cell-wall, and thus, with the absence of the nucleus, closely resemble a granulated state of that organ.

Vesicula.—I would propose this name for the "Contracting Vesicle," on account of the latter being a loose and inconvenient term in description (figs. 3 *c*, 4 *b*). It is certainly the most striking organ of the Infusoria, from its defined circular outline when distended, its hyaline aspect, and above all its sudden disappearance and gradual return at intervals, which give it a pulsatory character, so like that of a heart, that at first we are inclined to conclude that it must be the representative of this organ in the Infusoria. Spallanzani considered it a respiratory organ*; Ehrenberg the male organ of generation†; and Siebold a circulatory organ‡. The following facts, however, would seem to show that it is neither of these, but an excretory organ, viz.:—

1st. It is always seen either close to the pellicula, or close to the buccal cavity, and always stationary. Thus, in *Paramecium aurelia,* it is close to the surface, and although it of course passes out of view as the animalcule turns on its long axis, yet it always reappears, after contraction, in the same place (figs. 68 *a a*, 74 *f f*); while in *Vorticella* it is attached to the buccal cavity, and, being centrically situated, seldom passes out of view, except when it disappears under contraction, after which it also reappears in the same place.

2nd. In *Actinophrys Sol*§, and other *Amœbæ,* during the act of dilatation, the vesicula projects far above the level of the pellicula, even so much so as occasionally to form an elongated, transparent, mammilliform eminence, which, at the moment of contraction, subsides precisely like a blister of some soft tenacious substance that has just been pricked with a pin (fig. 24 *a*).

3rd. Lastly, when we watch the contraction of the vesicula in a recently encysted *Vorticella,* we observe that at the same moment that it contracts the buccal cavity becomes filled with fluid; and further, that this fluid disappears from the buccal cavity, and all trace of the latter with it, long before the vesicula reappears; thus proving at once, that the fluid comes from the vesicula and does not return to it, whatever may become of it afterwards (fig. 78).

The position of this organ, then, its manner of contracting,

* *Ap.* Dujardin, *op. cit.* pp. 103, 104. † *Idem,* pp. 105–108.

‡ *Ap.* Claparède, Ann. & Mag. Nat. Hist. vol. xv. p. 212, 1855.

§ *Idem, loc. cit.* pl. viii. fig. 1.

and the buccal cavity of encysted *Vorticella* becoming filled with fluid the moment it disappears (where we know it to be attached to the buccal cavity, and not to the pellicula), are almost conclusive of its excretory office. We have now to find out how this fluid is brought to the vesicula.

It will be remembered that there is a series of fusiform sinuses which surround each of the vesiculæ in *Paramecium aurelia*, and some other animalcula of this class, on which Spallanzani made the important observation, that as they become empty the vesicula becomes filled*. This may be easily seen, as well as that they do not reappear until some time after the vesicula has contracted. Thus we infer, that the fluid with which the vesicula is distended comes through the sinuses, but is not returned by them to the body of the *Paramecium*.

Now in some cases, faint hyaline or transparent lines may be seen to extend outwards† from each of these sinuses, which lines, Eckhard has stated, "traverse the body in a stellate manner." Hence, when we add Eckhard's evidence (which I have been able to confirm in a way that will be presently described) to the observation of Spallanzani, and connect this with the facts already adduced in favour of the excretory office of the vesicula, it does not seem unreasonable to conclude that the whole together forms an excretory vascular system, in which the vesicula is the chief receptacle and organ of expulsion.

While watching *Paramecium aurelia*, I on several occasions not only observed that the vesiculæ were respectively surrounded by from seven to twelve pyriform sinuses of different sizes, and that lines extended outwards from them in the manner described by Eckhard; but I further observed that these lines were composed of a series of pyriform or fusiform sinuses, which diminished in size outwards; and frequently I could trace as many as three in succession, including the one next the vesicula (fig. 66 *b b*). Hence I am inclined to infer, that this vascular system throughout is more or less composed of chains of such sinuses, and that all have more or less contractile power like that of the vesicula. Just preceding death, when *Paramecium aurelia* is compressed, and under other favourable circumstances, these sinuses run into continuous hyaline lines, and may not only be seen extending in a radiated, vascular form across the animalcule, but even branching out round the position of the vesicula, which, having now become permanently contracted, has thus poured back the contents which render them visible (fig. 67 *b b*). They enter

* Spallanzani *ap.* Dujard. *op. cit.* p. 103; Spall. Opusc. Phys. trad. Franç. t. i. p. 248.

† Ann. & Mag. Nat. Hist. vol. xviii. p. 448, 1846.

the lower or inner part of the organ, and at this point, therefore, are pushed inward as the vesicula becomes distended (fig. 68 *a a*). Under the same circumstances, also, when the vesicula is slowly dilating and contracting, it may be seen to be attached to a small papilla on the surface, about twice the diameter of those which surmount the trichocysts*, and through which it probably empties itself (fig. 68 *a a*). In *Otostoma* there appears to be a similar arrangement of vessels round each vesicula, and here also they seemed to me to be branched,—at least such was my impression after having watched this animalcule for a long time, in order to determine the point.

In *Amœba* and *Actinophrys* the vesicula is generally single; sometimes there are two, and not unfrequently in larger *Amœbæ* a greater number. In *Euglypha* I have not been able to recognize them, but in *Arcella vulgaris* and *Difflugia proteiformis* (figs. 79, 80) they may be seen in great number, situated round the margin of that part of the animalcule which is within the test; and from their always reappearing, after contraction, in the same places respectively, we may perhaps infer that the situation of the vesicula in *Amœba* and *Actinophrys* also is fixed, though from their incessant polymorphism it appears to be continually varying in position. In *Paramecium*, and Ehrenberg's Enterodela generally, the vesicula is either single or dual. When it exists in great number in any of these (*e. g. Chilodon cucullulus*, Ehr.), this appears to depend on accidental dilatations of the sinuses in connexion with it. Thus, in the animalcule just mentioned, where the vesicula is single, and seems to be subterminal and lateral in its normal position, it is not uncommon to meet with a group in which every member presents a variable number of contracting vesicles, variably also and irregularly dispersed throughout the body, without one being in the true position of the vesicula (figs. 82, 83). That the vesicula does make its appearance now and then may be inferred, as it perhaps may also be inferred that from over-irritability, or some such cause, it does not remain under dilatation long enough to receive the contents of the sinuses; and hence their accidental dilatation,

* These are narrow, fusiform cells, arranged perpendicularly, and at some little distance from each other, under the pellicula, where they thus form a layer all over the body, and each, according to Dr. Allman, contains a delicate, resilient thread, coiled up in its interior, which, just after the cells have been forcibly pressed out into the water, by crushing the animalcule, causes them to assume, for a second, a circular form, and then burst, through which the thread is set free, and, lying rigid on the glass, presents the form of an acicular crystal, terminated at each end by a pointed extremity, one of which, being more attenuated than the other, appears like an appendage. To these cells Dr. Allman has given the name of "trichocysts." (Quart. Journ. Microscop. Sc. vol. iii. p. 177, 1855.)

and the appearance of a plurality of vesiculæ. That, also, the sinuses which are in the immediate vicinity of the vesicula do empty themselves into it may be easily seen, when both are present; and what takes place near, it seems not unreasonable to infer may, through a concatenation of communication, take place from a distance. At the same time, the sinuses of this system in the sarcode of *Amœba* not only seem to burst into each other, and into the vesicula, but when the latter has contracted, another sinus, partially dilated, and situated near the border, may be seen to swell out and contract after the same fashion, before the reappearance of the vesicula (fig. 81 *a a*). Then there is no knowing how many vesiculæ there may be in *Amœba*; while *Actinophrys Sol*, Ehr., is surrounded by a peripheral layer of vesicles, which, when fully dilated, appear to be all of the same size, to have the power of communicating with each other, and each, individually, to contract and discharge its contents externally as occasion may require; though, generally, one only appears and disappears in the same place. In *Oxytricha* the vesicula is single or dual, but in *Plœsconia*, as far as my observation extends, always single. The vesicula is always single in *Vorticella*, where it is attached to the buccal cavity close to the anal orifice, as in *Rotifera* and the young of *Cyclops quadricornis* (fig. 74 *f*, *h*). In one species of *Vorticella* there is a distinct pouch for these excretory orifices, about half-way up the buccal cavity (fig. 75 *a*). In *Colepina* the vesicula occupies the posterior extremity.

Its existence in *Astasia*, *Anisonema*, and *Euglena* can only be determined by inference. They all have a transparent vesicle situated close to the anterior extremity; and in *Astasia* we know that it is thus situated close to the buccal cavity (fig. 45 *e*). In *Anisonema* it seems to alter in size and shape, as it does in some *Amœbæ*, without completely contracting; and in *Astasia* also it is at one time more defined and apparent than at another; but this may be owing to change of position in the entire animalcule. In *Polytoma Uvella* it is similarly situated, but double, and has been seen to contract by Schneider*; and in a small colourless animalcule, very much like a young *Astasia*, as well as in a minute species of *Chlamidomonas*, Ehr., I have frequently seen this vesicle contract and dilate in the manner of the vesicula; so that there can be little doubt about the vesicle in the anterior extremity of *Astasia*, *Anisonema*, and *Euglena* (fig. 49 *b*) being the homologue of the vesicula, though in the latter the red body be appended to it; this, however, is not the case in the *Chlamidomonas* mentioned, where the red spot is nearly in the middle of

* Ann. & Mag. Nat. Hist. vol. xiv. p. 322, 1854.

the body, and peripheral, while the vesicula is in the anterior extremity.

The apparent quiescent state of the vesicula in *Astasia*, *Euglena*, &c. may be an approach to its disappearance altogether as a distinct organ, and therefore a step nearer to the vegetable kingdom. But Schneider, in allusion to this, quotes a passage from Cohn, in which the latter observes, that "internal pulsating spaces" have been discovered in "certain genera of Algæ;" on which Schneider justly remarks, that if they "occur in the swarm-cells of *Confervæ*, they certainly cease to be a characteristic of animal nature*;"—thus rendering useless another distinguishing point between animals and plants at this part of the organic kingdom, which after all, perhaps, may be found to have its homologue in the vacuoles of the vegetable protoplasm.

That the vesicula is a distinct organ, and not merely a space like the digestive globule, might be inferred from its always occurring in the same place in the same species; but in addition to this, the fact was on one occasion most satisfactorily demonstrated to me by its remaining pendent in a globular form to the buccal cavity of a *Vorticella*, when, by the decomposition of the sarcode, and evolution of a swarm of rapidly moving monadic particles, these two organs, with the cylindrical nucleus or gland, though still slightly adhering to each other, were so dissected out as to be nearly separate; and thus yielding in position from time to time, as they were struck by the little particles, their forms and relative positions respectively became particularly evident (fig. 76 *a*).

Although globular in shape, yet, as before stated, it is accompanied in *Paramecium aurelia* by a variable number of pyriform sinuses, which are arranged around it in a stellate form. In most of the other animalcules these are globular, and, under exhaustion of the animalcule from various causes, are frequently so distended, and thus so approximated, as to assume the appearance of an areolar structure, immediately in contact with the vesicula (fig. 84). Each globular sinus, however, would appear to be the proximal or largest of a concatenation of smaller ones, which diminish in size with their distance from the vesicula (fig. 82 *d*). The vesicula becomes doubled preparatory to fissiparation, and therefore appears dual in *Vorticella*, and quadruple in *Paramecium*, &c. (fig. 69); and it is interesting to find that in the metamorphosis of the former into *Acineta* it frequently acquires a plurality similar to that which obtains in the Rhizopoda generally†.

* *Loc. cit.* p. 330.

† See particularly Stein's work on the Development of Infusoria.

Of the use of the vesicula, and its vascular system, we are at present ignorant, further than that its functions are excretory; and when we observe the quantity of water that is taken into the sarcode with the food, and try to account for its disappearance, it does not seem improbable that the vesicula and its vessels should be chiefly concerned in this office. Another service, however, which it performs, is to burst the spherical membranes of *Vorticella* and *Plæsconiæ* when they want to return to active life after having become encysted: this it effects by repeated distension, until the lacerated cyst gives way sufficiently for the animalcule to slip out. At these times, also, the animalcule is rendered so spherical by this distension that it is also evidently one way by which the Infusoria might assume this form (fig. 12). Hence, in describing the sarcode, I have expressed a doubt whether the water in an *Amœba,* when distended in this manner, be in its centre or in the cavity of the vesicula. Certainly, when *Amœba* is in the form of a sphere, I never have been able to see the vesicula, while all the other elements of the cell have been perfectly plain; added to which, under these circumstances, a part of the cell-wall is generally transparent, from the absence of the sarcode and its granules, which would be the case if the vesicula were the cause of the distension, since in *Amœba* it is attached to the pellicula, and therefore no sarcode exists immediately opposite this point (fig. 13).

Should it have any other uses, they are probably similar to those of the "Water Vascular System" of Rotifera, which in *Brachionus Pala,* one of the largest species of this class, consists of a corrugated sac when empty (like the bladder of mammalia), opening by a constricted neck into a heart-shaped cloaca close to the termination of the alimentary canal; and, when distended, presenting (*mihi*) a single vessel opening into its fundus, and then passing down through its side towards the neck, where it divides into two, which respectively run up laterally to the anterior extremity of the body, bearing in their course four monociliated (Huxley)* pyriform diverticula, and probably terminating, as in *Lacinularia*†, partly in junction and partly in blind tubes. The vacuolar structure attached to these vessels may be analogous to the vacuolar structure connected with the vesicula in the Infusoria, and it would be interesting to determine if the vacuoles in it occasionally diminish in size or disappear, or become dilated when from disease or approaching death the vesicula itself is unnaturally and permanently distended. Should the lateral vessels not terminate in *Brachionus Pala,* as above mentioned, then they must, as appears to be the case in the other

* Quart. Journ. Microscop. Sc. vol. i. p. 7. † *Idem.*

Rotifera open into the vesicula close to its communication with the cloaca.

It might be asked here, if all vacuolar dilatations of the sarcode belong to this excretory system of sinuses; that is, excepting those made by the buccal cavity in the manner mentioned? Certainly, where there is a plurality of actively contracting vesicles, without the appearance of the vesicula, as in *Chilodon cucullulus*, we may, as before stated, attribute this to a kind of over-irritability or constrictive spasm of the vesicula, and, therefore, consider that these vesicles are accidental dilatations of the sinuses in connexion with it; as we may set down the dropsical state of *Himantophorus Charon* (Ehr.), and other animalcules of the kind, to an opposite condition of this organ, viz. that in which it is unable to relieve itself of its contents (fig. 84): this I have often seen occur under my own eyes. But there is an intense vacuolar state of the sarcode that occasionally presents itself in *Amœba*, which makes it look like an areolar tissue composed of vesicles diminishing to a smallness that cannot be determined by the microscope,—such as is seen in the advancing border of *Spongilla* when issuing from the seed-like body, and in the protoplasm of the vegetable cell: whether this still be a part of the vesicular system or not, I am unable to decide; at the same time, the contracting vesicles in the transparent growing border of the new-developing sponge are so numerous, and so like those which are seen in the protoplasm of the last cell under formation of the stem and roots of *Chara* when budding from the nucule, that we cannot fail to see a most striking analogy between the two, even if we cannot reconcile ourselves to the former being a part of the vascular system attached to the vesicula; indeed, in the new nucleus itself of the roots of *Chara*, vesicles do appear and disappear.

Lastly, from the presence of the vesicula in *Spongilla*, and its being so constant in the Rhizopoda generally, and so numerous in *Arcella vulgaris*, it does not seem altogether unreasonable to infer that the streams of water which issue from the great canals of *Spongilla* are produced by the continued pouring into them, from the vesiculæ of the different sponge-cells, the superfluous water which they imbibe by endosmiosis, apparently, during nutrition; for the type of *Spongilla* is to be surrounded with a general pellicula, in which there is only one excretory opening, and through which pellicula the ends alone of the spicula project in bundles; nor does it seem altogether far-fetched to conceive that the offices of glandular organs in higher developments may be performed, in some instances, after this fashion.

[To be continued.]